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**APPLICATION FOR  
UNITED STATES UTILITY LETTERS PATENT**

Be it known that we, Karl A. Belser, a citizen of the United States of America, residing at 5544 Drysdale Drive, San Jose, County of Santa Clara, and State of California 95124 of the United States of America, Neil Deeman, a citizen of Great Britain, residing at 101 Leona Court, Alamo, County of Contra Costa, and State of California 94507 of the United States of America, and Ga-Lane Chen, a citizen of the United States of America, residing at 150 Estrella Road, Fremont, County of Alameda, and State of California 94539 of the United States of America, have invented certain new and useful improvements in a

**METHOD FOR REPLICATING MAGNETIC PATTERNS ON HARD  
DISK MEDIA**

of which the following is the Specification:

I hereby certify that this correspondence is being deposited with the United States Postal Service as Express Mail No. ET198092474US in an envelope addressed to: BOX PATENT APPLICATION, Assistant Commissioner for Patents, Washington, D.C. 20231, on April 19, 2001.

Nancy R. Simon  
(Signature)

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to and claims the benefit of commonly assigned United States Provisional Application No. 60/198,192, filed on April 19, 2000 and entitled "Method For Replicating Magnetic Patterns On Hard Disk Media." The subject matter of this related application is incorporated herein by reference.

## BACKGROUND

## 1. Field of the Invention:

This invention relates to magnetic recording media, such as the magnetic recording media used in hard disk drives, and in particular to a method for fabricating magnetic recording media. Still more particularly, the present invention relates to a method for replicating magnetic patterns on hard disk media.

## 2. Description of the Prior Art:

Designers, manufacturers, and users of computing systems require reliable and efficient digital information storage and retrieval equipment. Conventional magnetic disk drive systems are typically used and are well known in the art. As the amount of information that is stored digitally increases, however, users of magnetic recording media need to be able to store larger and larger amounts of data. To meet this demand, designers of magnetic recording media are working to reduce the size of the features on a recording disk, because the storage capacity of a recording disk is a function of the number of closely spaced concentric tracks on the disk. Some of the recording disk surface area, however, must be used for purposes other than data storage.

1       Conventional magnetic storage disks utilize various types of indexing  
2 marks and alignment indicia to help keep the head properly aligned on a  
3 particular track. These marks and indicia are often recorded in servo sectors,  
4 which are angularly-spaced reserved portions of the recording disk surface that  
5 extend out approximately radially from the disk centers. Servo sectors use  
6 recording disk surface area that could otherwise be used for data storage.  
7 Consequently, servo sector information must be stored as efficiently as possible  
8 in order to provide users with the most storage capacity possible.  
9

10      Additionally, as the demand to store more data on each disk increases,  
11 designers are increasing the number of tracks on each disk. However, with track  
12 densities at and exceeding ten thousand tracks per inch, the tasks of increasing  
13 data storage capacity and writing servo patterns with suitable geometric  
14 accuracy are becoming increasingly difficult. Therefore, developing new  
15 techniques for manufacturing magnetic recording media remains a significant  
16 consideration for designers, manufacturers, and users of contemporary electronic  
17 devices.

## SUMMARY

3 In accordance with the present invention, a system and method are  
4 disclosed for replicating magnetic patterns on hard disk media. In one  
5 embodiment, a pattern is formed in a mask and the mask is placed over or above  
6 a recording layer. The recording layer may include a single, dual, or multi-layer  
7 recording layer. The pattern defines the recordable regions and the non-  
8 recordable regions to be created in one or more layers within the recording layer.  
9 The magnetic properties of portions of the recording layer are then altered in  
10 order to create recordable or non-recordable regions. The mask is then removed  
11 from the recording layer.

13 In certain embodiments, the mask may comprise a photoresist layer that is  
14 exposed to a light source and then developed such that portions of the  
15 photoresist layer are removed. Portions of the recording layer that correspond to  
16 the removed portions of the photoresist layer are then uncovered. The  
17 uncovered portions of the recording layer may then be exposed to a plasma  
18 treatment. Ions within the plasma interact with one or more layers in the  
19 exposed portions of the recording layer to change the magnetic properties of the  
20 exposed regions. The remaining photoresist layer may then be removed.

22 In other embodiments, the mask may comprise a resist layer and the  
23 pattern is formed in the resist layer using imprint lithography. One method for  
24 performing imprint lithography is to use a stamper to imprint the desired pattern  
25 into the resist layer. After the pattern is imprinted in the resist layer, portions of  
26 the resist layer are compressed while other portions of the resist layer are at or  
27 near their original thickness. The compressed portions of the resist layer are then  
28 removed in order to expose corresponding portions of the recording layer. The  
29 uncovered portions of the recording layer may then be exposed to a plasma  
30 treatment. The magnetic properties of one or more layers in the exposed regions

1 of the recording layer are altered by the plasma and differ from the magnetic  
2 properties of the regions covered by the resist layer.

3

4 In yet other embodiments, one or more layers within the exposed portions  
5 of the recording layer may be etched prior to the plasma treatment. The etch  
6 creates grooves in the exposed regions of the recording layer. The grooves may  
7 compensate for any expansion in the recording layer caused by the plasma  
8 treatment.

## BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, and further objects and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

**Figure 1** is a diagram of a data storage system that may be used with the present invention;

**Figure 2** is a diagram depicting an upper surface of a recording disk utilized in the disk drive assembly of **Figure 1**;

**Figure 3** is a linearized diagram of one embodiment of a sector of the recording disk illustrated in **Figure 2**;

**Figures 4(a) – 4(e)** are diagrams illustrating an exemplary method for replicating magnetic patterns on a hard disk media according to one embodiment of the present invention;

**Figures 5(a) – 5(f)** are diagrams depicting an exemplary method for replicating magnetic patterns on a hard disk media according to another embodiment of the present invention; and

1       **Figure 6** is a flowchart illustrating an exemplary method for replicating  
2 magnetic patterns on a hard disk media according to another embodiment of the  
3 present invention.

## DETAILED DESCRIPTION

To facilitate an understanding of the present invention, it is described hereinafter in the context of a specific embodiment. In particular, reference is made to the implementation of the invention in a magnetic hard disk media for a hard disk drive. It will be appreciated, however, that the practical applications of the invention are not limited to this particular embodiment. Rather, the invention can be employed in other types of magnetic recording media, one example being magneto-optical hard disk media.

With reference now to the figures and in particular with reference to **Figure 1**, a data storage system that can be used with the present invention is shown. Data storage system 100 in this exemplary embodiment is a hard disk drive system. Data storage system 100 includes one or more storage disks 102, a storage system controller 104, an actuator 106, a voice coil motor 108, a recording head 110, and a rotating spindle 112. The recording head 110 is comprised of at least one read head and at least one write head, and is positioned at the end of actuator 106. Actuator 106 is moved via voice coil motor 108. The recording head 110 transfers data between storage system controller 104 and a specific physical location on storage disk 102. Data is preferably stored in many approximately consecutively numbered concentric rings or "tracks" 114 on storage disk 102. For clarity, only two tracks 114 are shown in **Figure 1**. The tracks are displaced radially from each other, beginning at the inner diameter 116 of the disk 102 and continuing to the outer diameter 118 of the disk 102.

Storage system controller 104 may randomly access a specific logical location on storage disk 102 via a particular track address and a particular sector address. Tracks 114 are very closely spaced in order to maximize storage capacity and economy. The mechanical precision of the movement of storage disk 102 and the movement of recording head 110 is critical to accessing the

1 proper data storage location on storage disk 102. Storage system controller 104  
2 thus requires some means for precisely positioning recording head 110 quickly  
3 and accurately over tracks 114 for subsequent storage and retrieval operations.

4

5 Referring now to **Figure 2**, a diagram of a surface of an exemplary storage  
6 disk is illustrated. The surface 200 of storage disk 102 typically includes a  
7 landing zone 202, a useable data zone 204, arc-shaped sectors 206, and an arc-  
8 shaped path 208 taken across the surface 200 by recording head 110. A linearized  
9 diagram of an exemplary sector 206 is shown in **Figure 3**. Sector 206 includes a  
10 servo sector 300, a data wedge 302, a pair of neighboring numbered concentric  
11 tracks 304 and 306, and a border 308 between landing zone 202 and useable data  
12 zone 204. Data wedge 302 includes stored user data, while servo sector 300  
13 includes address and alignment information (e.g. servo marks) used by the disk  
14 drive system. The present invention can be used to replicate magnetic patterns  
15 in servo sectors and/or data wedges.

16

17 Referring to **Figures 4(a) – 4(e)**, diagrams illustrating an exemplary  
18 method for replicating magnetic patterns on a hard disk media according to one  
19 embodiment of the present invention are shown. **Figure 4a** depicts a substrate  
20 400, which can be comprised of a glass ceramic substrate, an aluminum  
21 substrate, or an aluminum substrate with a nickel phosphorus coating. A  
22 recording layer 402 lies on the surface of the substrate 400, and is used to write  
23 data to, and read data from, the storage disk. In this exemplary embodiment, the  
24 recording layer 402 is comprised of a magnetic recording layer. Recording layer  
25 402 typically has a thickness of approximately ten to twenty nanometers.

26

27 In this exemplary embodiment, the recording layer 402 is comprised of a  
28 cobalt chromium (CoCr) layer. Those skilled in the art will appreciate, however,  
29 that other materials can be used for the recording layer. Examples include, but  
30 are not limited to, cobalt chromium platinum (CoCrPt) and cobalt chromium  
31 platinum boron (CoCrPtB).

1  
2 Furthermore, in certain embodiments, the recording layer may include,  
3 but is not limited to, two or more layers. For example, the recording layer 402  
4 may be a dual-layer recording layer comprised of a first layer and a second layer.  
5 The first layer may include, but is not limited to, a chromium layer (Cr). The  
6 second layer may include, but is not limited to, a cobalt chromium (CoCr) layer.  
7 However, other materials may be used for the first and second layers, such as  
8 cobalt platinum (CoPt), cobalt palladium (CoPd), or cobalt-platinum platinum  
9 (CoPt/Pt).

10  
11 Alternatively, recording layer 402 may be configured as a multi-layer  
12 recording layer. The multi-layers may be comprised of, but not limited to,  
13 alternating layers of cobalt platinum (CoPt), cobalt palladium (CoPd), or cobalt-  
14 platinum platinum (CoPt/Pt). The materials configured in a multi-layer  
15 recording layer are determined by their properties. A first layer (or layers) is  
16 typically grown on the surface of the substrate in order to promote the proper  
17 crystal orientation and enhance magnetic performance, while the additional  
18 layers overlying the first layer are configured to create a desired coercivity and  
19 enhance magnetic performance.

20  
21 Referring again to **Figure 4(a)**, a mask 404 overlies the recording layer 402.  
22 The mask 404 includes a pattern to be formed in the recording layer 402, wherein  
23 the pattern defines the recordable and non-recordable areas to be created in one  
24 or more layers within the recording layer 402. The mask 404 may be  
25 implemented and configured in any desired manner. For example, the mask 404  
26 may be comprised of, but is not limited to, a resist layer, a photoresist layer, a  
27 silicon, or a silicon dioxide layer. Any material that can be patterned may be  
28 used as a mask.

29  
30 **Figure 4(b)** illustrates the mask 404 after the mask has been exposed to a  
31 pulsating laser, electron, or ion beam, where the pulsing of the beam is

1 determined by the desired pattern to be created in the recording layer 402. The  
2 mask 404 is then developed, such that portions of the mask 404 are removed.  
3 With a negative photoresist, for example, those portions exposed to a light source  
4 are removed. Alternatively, with other types of resist materials, such as a  
5 positive photoresist, the areas not exposed to the light source are removed.

6  
7       Once portions of the mask 404 are removed, regions of the recording layer  
8 406 corresponding to the removed mask are exposed. In certain embodiments, an  
9 etch may then be performed to create grooves 408 in the recording layer 402  
10 (**Figure 4(c)**). The etch may be implemented in any desired manner. For  
11 example, a reactive ion etch may be performed.

12  
13       The structure is then exposed to a plasma 410, as shown in **Figure 4(d)**.  
14 The plasma 410 overlies the exposed regions 406 of the recording layer 402 and  
15 the remaining mask 404. Ions within the plasma 410 interact with the exposed  
16 regions 406 of the recording layer 402 to alter the magnetic properties of the  
17 exposed regions 406 of the recording layer 402. The plasma 410 may be  
18 implemented and configured in any desired manner. For example, the plasma  
19 410 may include, but is not limited to, a sputtering oxidation, such as an argon,  
20 or argon and oxygen, gas. However, other types of plasma 410 may be used with  
21 the present invention. The type of plasma used will be determined by how well  
22 the plasma changes the magnetic properties in the exposed regions of the  
23 recording layer. Thus, the selection of the plasma may depend upon the material  
24 or materials in the recording layer.

25  
26       In certain embodiments, the plasma 410 may alter one or more layers  
27 within recording layer 402 physically. Thus, the grooves 408 (**Figure 4(c)**) may  
28 compensate for any expansion in the recording layer caused by the plasma. The  
29 depth of the etch may depend on the thickness of the recording layer and the  
30 type of plasma used. When completed, the surface of the recording layer 402

1 should be flat or near flat such that a recording head is not disturbed as it flies  
2 over the recording layer.

3

4 **Figure 4(e)** illustrates the structure after the remaining mask 404 is  
5 removed. The resulting recording layer 402 comprises areas of differing  
6 magnetic properties. The regions 412 of the recording layer 402 that were  
7 exposed to the plasma 410 have different magnetic properties than the regions  
8 414 of the recording layer 402 that were covered by the mask 404.

9

10 Thus, the present invention can be used to create recordable regions and  
11 non-recordable regions in a recording layer. For example, if the recording layer  
12 is comprised of a high coercivity media that is non-recordable with conventional  
13 recording heads, the present invention can be utilized to create regions 412  
14 having a lower coercivity level. These regions 412 of lower coercivity then  
15 become recordable, and can be used to store data, including servo data, on the  
16 storage disk. Alternatively, if the recording layer is comprised of a low  
17 coercivity media that is recordable, the present invention can be utilized to create  
18 regions 412 having a lower coercivity level. These regions 412 of lower coercivity  
19 then become non-recordable, and can be used to define the areas on a storage  
20 disk that can be used to store data.

21

22 **Figures 5(a) – 5(f)** are diagrams depicting an exemplary method for  
23 replicating magnetic patterns on a hard disk media according to another  
24 embodiment of the present invention. **Figure 5(a)** depicts a substrate 400, which  
25 can be comprised of a glass ceramic substrate, an aluminum substrate, or an  
26 aluminum substrate with a nickel phosphorus coating. A recording layer 402 lies  
27 on the surface of the substrate 400, and is used to write data to, and read data  
28 from, the storage disk. A mask 404 overlies the recording layer 402. The  
29 discussion regarding the substrate, recording layer, and mask above apply to this  
30 embodiment as well and therefore will not be repeated.

31

1        A stamper 500 is then pressed into the mask 404 in order to transfer a  
2 pattern from the surface of the stamper 500 into the surface of the mask 404.  
3 **Figure 5(b)** shows how portions of the mask 404 are compressed 502, while other  
4 portions of the mask 404 are at or near their original thickness. The compressed  
5 portions 502 of the mask 404 are then removed in order to expose portions 504 of  
6 the recording layer 404 (**Figure 5(c)**). The removal of the compressed portions 502  
7 of the mask 404 may be implemented in any desired manner. For example, the  
8 compressed portions 502 may be removed using a vacuum etch process, such as  
9 a sputter etch or a reactive ion etch.

10  
11        Once portions of the mask 404 are removed, regions of the recording layer  
12 504 corresponding to the removed mask are exposed. In certain embodiments, an  
13 etch may then be performed to create grooves 506 in the recording layer 402  
14 (**Figure 5(d)**). The etch may be implemented in any desired manner. For example,  
15 a reactive ion etch may be performed.

16  
17        The structure is then exposed to a plasma 508, as shown in **Figure 5(e)**.  
18 Ions within the plasma 508 interact directly with the exposed regions 504 of the  
19 recording layer 402. The plasma 508 may then alter the magnetic properties of  
20 the exposed regions 504 of the recording layer 402. The plasma 508 may be  
21 implemented and configured in any desired manner. For example, the plasma  
22 508 may include, but is not limited to, a sputtering oxidation, such as an argon or  
23 argon and oxygen plasma. However, other types of plasma 508 may be used  
24 with the present invention. The type of plasma used will be determined by how  
25 well the plasma changes the magnetic properties in the exposed regions of the  
26 recording layer. Thus, the selection of the plasma may depend upon the material  
27 or materials in the recording layer.

28  
29        The remaining mask 404 is then removed, as shown in **Figure 5(f)**. The  
30 resulting recording layer 402 comprises areas of differing magnetic properties.  
31 The regions 510 of the recording layer 402 that were exposed to the plasma 508

1 have different magnetic properties than the regions 512 of the recording layer 402  
2 that were covered by the mask 404. As with the earlier embodiments, the present  
3 invention can be used to create recordable regions and non-recordable regions in  
4 a recording layer.

5

6 As discussed above, the embodiment of **Figure 5** utilizes a stamper 500 to  
7 imprint a desired pattern in the mask. One method for making a stamper 500  
8 will now be described. The present invention, however, is not limited to this  
9 method. Any technique that creates a device for imprinting a pattern into the  
10 mask may be used with the present invention.

11

12 The stamper 500 may be comprised of a metal layer, such as nickel, and  
13 is created from a master disk. A master disk is a recording disk that is  
14 manufactured using very specialized machinery in order to obtain precise  
15 positional and geometric features. A master is usually made by taking a  
16 polished glass disk and spin-coating a thin layer of photoresist material over a  
17 surface of the glass disk. The photoresist material typically used is Novolak with  
18 DNQ active components.

19

20 The photoresist material is then exposed to a pulsating laser, electron, or  
21 ion beam, where the pulsing of the beam is determined by the desired format  
22 pattern that is to be patterned into a magnetic media. A programmable formatter  
23 provides the necessary signal to modulate the recording laser beam with the  
24 desired format pattern. In the present invention, the format patterns can vary  
25 from one disk drive model to another, so the formatter is programmable in order  
26 to output the desired modulated signals for a specific format pattern.

27

28 The laser, electron, or ion beam output by the formatter has the ability to  
29 define very small features, such as one hundred nanometers in size or smaller.  
30 Having the ability to define small or very dense format patterns means these

1 small format patterns will be transferred to the stamper 500, which in turn means  
2 the small format pattern will be transferred to the mask 404.

3

4       Once the photoresist layer has been selectively exposed, the exposed areas  
5 are removed by washing them away with a developing solution. The remaining  
6 portions of the photoresist layer define the desired format pattern. A first  
7 stamper is then made from the master disk by sputtering or evaporating a metal  
8 layer directly onto the photoresist layer. Since the deposition rate is relatively  
9 slow, only a thin layer of metal is coated over the photoresist layer in a  
10 reasonable time. Therefore, in order to make the first stamper more robust, an  
11 electroplating process is used to form a thicker layer of metal on the first  
12 stamper. Nickel is typically the metal used in the electroplating process, and the  
13 first stamper usually reaches a thickness of 0.3 millimeters.

14

15       The first stamper is then peeled away from the photoresist layer and is  
16 commonly used to create copies. A copy of the first stamper is created by first  
17 passivating the first stamper by providing a monolayer of oxide on the surface of  
18 the metal stamper. Passivation can be accomplished chemically by dipping the  
19 first stamper into an oxidizing solution, or electrochemically by making the first  
20 stamper an anode in an electrical circuit. After a thin layer of oxide forms on the  
21 surface of the first stamper, another electroplating process is performed and a  
22 layer of metal forms over the oxide layer. The layer of metal is then peeled away  
23 from the first stamper, whereby the layer of metal forms a copy of the first  
24 stamper. This copy, however, has a reverse image of the format pattern on its  
25 surface. So the copy is passivated and an electroplating process is performed in  
26 order to fabricate a second copy. Now, the second copy has the same format  
27 pattern as the first stamper, and the second copy is then used to form the desired  
28 pattern into the mask.

29

30       The process described above is known in the art as a "family making  
31 process." The first stamper is known as the "father", and the copy of the first

1 stamper is known as the "mother". The mother contains the reverse image of the  
2 format pattern. The second copy is known as the "son." The mother can be  
3 recycled many times in order to create a plurality of sons. Furthermore, the sons  
4 can be used multiple times, making them the perfect tool for a mass  
5 manufacturing process.

6  
7 Referring to **Figure 6**, a flowchart illustrating an exemplary method for  
8 replicating magnetic patterns on a hard disk media according to another  
9 embodiment of the present invention is shown. The method begins at block 600,  
10 and thereafter passes to block 602 where a mask is applied on the surface or  
11 above the surface of the recording layer. Next, the desired pattern is created in  
12 the mask (block 604). The pattern may be created in any desired manner. For  
13 example, the pattern may be created using photolithography or imprint  
14 lithography.

15  
16 In certain embodiments, however, the steps depicted in blocks 602 and 604  
17 may be performed in the reverse order. The pattern may be created in the mask  
18 and then the mask may be placed on or over the recording layer.

19  
20 Referring now to block 606, a determination is then made as to whether or  
21 not portions of the mask should be removed. For example, if imprint  
22 lithography was used to create the pattern, the compressed portions of the mask  
23 may need to be removed. If portions of the mask are to be removed, the process  
24 continues at block 608 with the removal of the desired portions of the mask.

25  
26 If, however, portions of the mask do not need to be removed, the process  
27 passes to block 610, where a determination is made as to whether or not an etch  
28 should be performed. For example, grooves may need to be created in one or  
29 more layers within the recording layer if portions of the recording layer will be  
30 changed physically when exposed to the plasma. If an etch is to be performed,  
31 the process passes to block 612 where an etch is performed.

1

2        If however, an etch does not need to be performed, the process continues  
3    at block 614 where the magnetic properties of portions of the recording layer are  
4    altered. Changing the magnetic properties of portions of the recording layer may  
5    be implemented in any desired manner. For example, exposure to a plasma may  
6    be performed.

7

8        Once the magnetic properties of portions of the recording layer have been  
9    changed, any remaining layers overlying the recording layer are removed. This  
10   step is illustrated in block 616. The resulting recording layer now comprises  
11   areas of differing magnetic properties, thereby creating recordable regions and  
12   non-recordable regions in the recording layer. The method then ends, as shown  
13   in block 618.

14

15        While the invention has been particularly shown and described with  
16   reference to a preferred embodiment, it will be understood by those skilled in the  
17   art that various changes in form and detail may be made therein without  
18   departing from the spirit and scope of the invention.